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AIR CUSHION VEHICLE (ACV) ICEBREAKER TEST AND EVALUATION PROGRA--ETC(U)
JUL 78 J BUCK , C W PRITCHETT DOT-CG-81-1856
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This report is an Executive Summary of the work reported in Volume II, "Operational and Engineering Analysis: ACV Icebreaker Test and Evaluation Program."

16. Abstract
During the winter ice season, November 1977 through March 1978, the U.S. Coast Guard R&D Center, Avery Point, Connecticut, conducted an operational test program to evaluate air cushion vehicles as icebreakers. The vehicles used were the MACKACE ACV barge and the self-propelled LACV-30. Tests were conducted on the Illinois and Mississippi Rivers with operations centered around Peoria, Illinois. The MACKACE ACV was used solely to facilitate river commerce while the LACV-30 was used in this role and also for flood control purposes. Extensive operational tests were conducted which produced data concerning icebreaking techniques and the effects of icebreaking on river commerce. Tests also established information on design criteria for ACV icebreakers, their maneuverability and control, operating costs and impact on Coast Guard personnel and facilities. As a result of the test program, significant advances were made in understanding ACV icebreaking procedures. The characteristics of ice were studied, and the necessity for developing ice classification and an icebreaking effectiveness methodology was identified.

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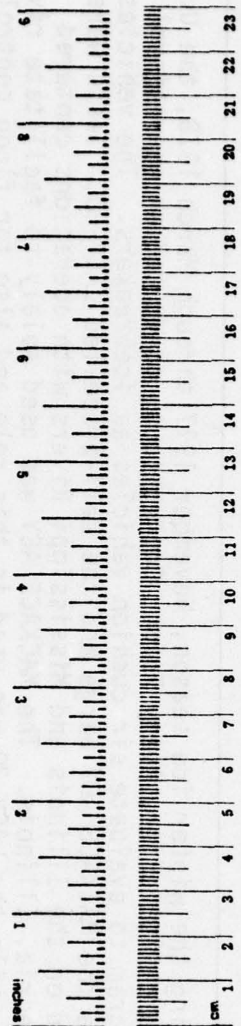
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

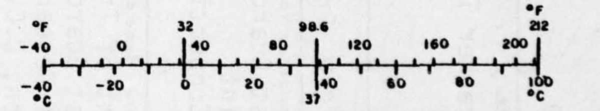
Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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Second Coast Guard District and participating units and commands

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U.S. Army, Transportation School, Ft. Eustis, Virginia

U.S. Army, CRREL, Hanover, New Hampshire

U.S. Army, Corps of Engineers, Chicago District and Peoria and Joliet project offices.

ADMINISTRATIVE INFORMATION

In response to the Chief, Office of Operations, the Office of Research and Development (G-D) was assigned the responsibility of conducting a Test and Evaluation Program to determine the feasibility of using Air Cushion Vehicles (ACV's) as icebreakers in a river ice environment (Reference 1). The Chief of Operations forwarded a task statement to the Chief, Office of Research and Development (Reference 2), who assigned the responsibility for developing the test plan, conducting the operational and engineering tests, and preparing the final documentation to the Research and Development Center (Reference 3).

To carry out the ACV icebreaking operational/engineering test and evaluation program, two ACV craft, the MACKACE ACV barge and the self-propelled LACV-30, were obtained. The MACKACE ACV was obtained under a lease contract (Reference 4) from Mackley Ace, Inc. (USA), for the period of 1 December 1977 to 28 February 1978. The LACV-30 was obtained through the cooperation of the U.S. Army Corps of Engineers through a memorandum of understanding for the approximate period of 15 November 1977 to 15 March 1978 (Reference 5).

Engineering support services were obtained by the Research and Development Center through a contract with the firm of Chi Associates, Inc., Arlington, Virginia, who employed as part of their team a subcontractor, Giannotti and Buck Associates, Inc., Riverdale, Maryland (Reference 6).

The ACV icebreaking operational/engineering test and evaluation program was conducted on the Illinois and Mississippi Rivers with operations centered around Peoria, Illinois, in accordance with OPORDER CG 2-78. The operational base was the Coast Guard ANFAC (Aid to Navigations Facility) in East Peoria within the Second Guard District.

CONTENTS

ILLUSTRATIONS

1.0 INTRODUCTION

This document is Volume 1 of a two-part report concerning ACV icebreaking operations conducted by the U.S. Coast Guard on the Illinois and Mississippi Rivers during the winter of 1977-1978. Volume 1, The Executive Summary, presents a comprehensive description of key elements of the test program including an operational summary, results,conclusions and recommendations. Volume 2 of the report, Operational and Engineering Analysis: ACV Icebreaker Test and Evaluation Program, provides detailed operational and engineering information, including complete data on testing procedures, analysis and results (Reference 7).

2.0 BACKGROUND

The U.S. Coast Guard is charged with providing icebreaking services in the Great Lakes and on coastal and inland waterways in order to satisfy reasonable demands of commerce and control the potential of flooding. The severity of the 1976-1977 winter pointedly emphasized the consequences of inadequate icebreaking capabilities on inland waterways and their subsequent impact on river commerce. Heavy river ice affects the ability of towboats to transit rivers by reducing the number of barges pushed and increasing transit times. In addition, fuel consumption is significantly higher, and the vessels are subject to ice damage. The net result to the towboat industry is decreased revenues and increased costs.

Conventional icebreakers are restricted by draft so their effectiveness is limited in shallow waters. The Coast Guard has had vessels operating on

the Mississippi River system for many years, but they are primarily engaged in servicing aids to navigation and have proven ineffective for icebreaking purposes. In considering alternative methods of breaking ice, it was decided that air cushion vehicles should be studied more carefully.

Air cushion vehicles of various configurations had previously been tested as icebreakers in Canada and were considered to have potential for use on shallow or otherwise restricted waterways, such as the U.S. inland waterway system (Reference 8). The two basic ACV configurations successfully employed in the Canadian tests were nonself-propelled barges and self-propelled vehicles.

While it was apparent that ACV icebreaking technology had potential for application in the Coast Guard's icebreaking programs, it was not clear what its capabilities or limitations were nor what impact it would have in the areas of personnel, facilities and support services. To gain experience in some of these areas, the Coast Guard decided to conduct an Air Cushion Vehicles Icebreaker Test and Evaluation Program during the 1977-1978 ice season. Action was, therefore, initiated to obtain an existing nonself-propelled ACV which could be made available within the established time frame. This resulted in leasing a barge-type vehicle from Mackley Ace, Inc. (USA). The MACKACE ACV required a pusher tow boat, and the CGC SUMAC (WLR-311) was assigned to perform this task. Later, the U.S. Army made available, in a joint Army/Coast Guard venture, a LACV-30 (Lighter Air Cushion Vehicle with a 30-ton payload) self-propelled craft and crew.

Since the purpose of the study was to demonstrate and evaluate ACV icebreaking capabilities, it was necessary to emphasize operational testing rather than engineering and technological development. Hard engineering data were obtained by incorporating engineering measurements into as many

tests as possible. As a result, a significant amount of engi-
a was obtained.

ional tests commenced on 1 December 1977 and terminated on
78. Over 450 hours of ACV icebreaking tests were conducted by
craft during that time. The craft were used primarily to facili-
towboat commerce. In addition, the LACV-30 successfully demon-
versatility by breaking ice for flood control.

E DESCRIPTION

lly an air cushion vehicle is a craft whose weight is supported
n of air supplied by lift fans. The air cushion is maintained
raft by a flexible rubber-coated fabric skirt system. An ACV
be a nonself-propelled lift platform, i.e., barge-type, or it
active propulsion system and thus be self-propelled.

CKACE ACV is a nonself-propelled steel barge, simply designed and
ding to conventional boat construction techniques. Lift is ob-
two standard-type diesel engines which drive two centrifugal
speed of the barge-type ACV is limited to that of its pusher
gure 3-1 gives the general characteristics of this craft.

CV-30 is a hardened version of the standard commercial Bell
extron "Voyageur" air cushion vehicle. It is a fully amphibious
craft designed to transport military cargo payloads up to 30 short
port of the logistics over-the-shore (LOTS) mission. The LACV-30
by two Pratt & Whitney ST6T-76 engines which have a normal shaft
rating of 1,400 and a maximum horsepower rating of 1,800. The craft's

air management system is powered by a 140-horsepower auxiliary power unit (APU) manufactured by Alturdyne Corporation. The air management system provides filtered, positive pressure air for the engines. The system includes an axial fan, moisture separators, and filters. Figure 3-2 gives the general characteristics of the craft.

MACKACE ACV GENERAL CHARACTERISTICS

- GENERAL DIMENSIONS 45 FT. x 55 FT.
- TWO GENERAL MOTORS DIESEL ENGINES 600 HP EACH (MODEL 16 V 71-N, 2100 RPM)
- TWO ALLDAY & PEACOCK CENTRIFUGAL FANS SINGLE INLET, FLOW RATE : 4800 CFM EACH (1200 B.A. SISW, DESIGN RPM = 2000)
- TWO 1000 GALLON FUEL TANKS
- HOVER HEIGHT BETWEEN 4 FT. & 5 FT.
- CUSHION PRESSURE MAINTAINED BETWEEN 0.95 PSI & 1.3 PSI (DEPENDING ON BALLAST)

IDENTIFICATION TABLE

1. BOW RUNNING LIGHT
2. ENGINE #1 EXHAUST
3. ENGINE #1
4. FAN #1
5. STEPS TO OBSERVATION DECK & CONTROL CABIN
6. STORAGE AREA
7. GENERATOR
8. PUSHING PAD
9. DECK FLOOD LIGHTS
10. CONTROL CABIN
11. SPRAY SUPPRESSION SKIRT
12. FINGER SEGMENTS OF SKIRT SYSTEM

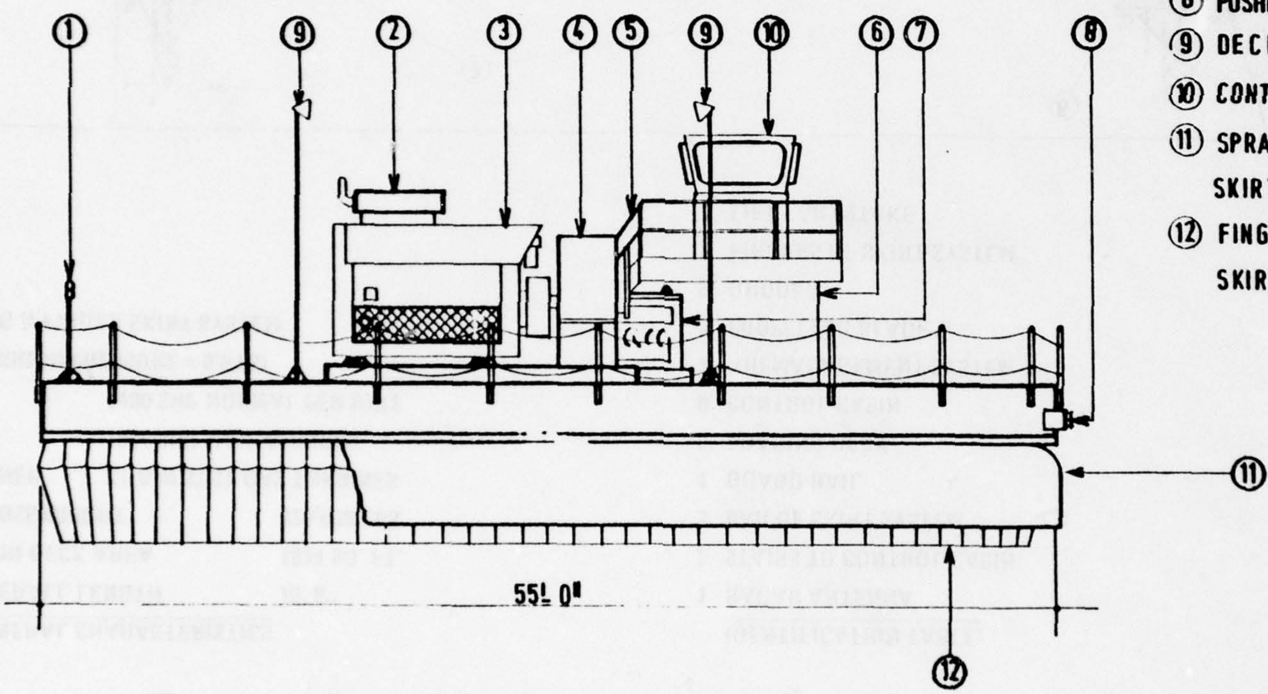


Figure 3-1: Mackace ACV-Profile
(NOTE : SPRAY SKIRT CUT BACK TO REVEAL SEGMENTS)

GENERAL CHARACTERISTICS

- OVERALL LENGTH 76'-6"
- MAIN DECK AREA 1674 SQ. FT.
- GROSS WEIGHT 125,000 LBS.
- POWER 2 P & W STGT GAS TURBINES
  1800 SHP MAX. PER UNIT
  1400 SHP NORMAL PER UNIT
- CUSHION PRESSURE = 0.5 PSI
- BAG & FINGER SKIRT SYSTEM

IDENTIFICATION TABLE:

1 RADAR ANTENNA
2 STAIRS TO CONTROL CABIN
3 BAG OF SKIRT SYSTEM
4 GUARD RAIL
5 LOADING DECK
6 CONTROL CABIN
7 AIR MANAGEMENT SYSTEM
8 PROPELLER BLADE
9 RUDDER
10 FINGERS OF SKIRT SYSTEM
11 LIFT FAN INTAKE

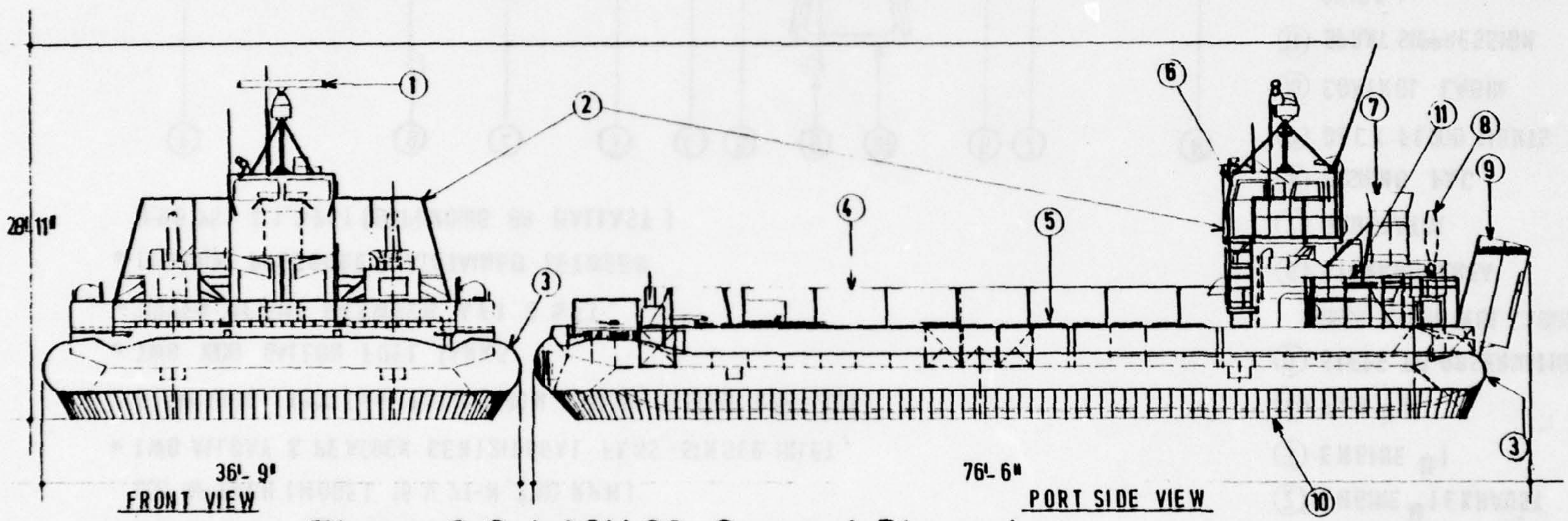


Figure 3-2: LACV-30 General Dimensions

The U.S. Coast Guard Cutter SUMAC (WLR-311) is the largest Coast Guard buoy tender in the Second District. For pushing the MACKACE ACV, SUMAC was modified by the addition of ice deflectors to protect its keel coolers, rudders, and propellers. Figure 3-3 gives the general characteristics of the SUMAC.

4.0 TEST OBJECTIVES

The test and evaluation program for both the nonself-propelled MACKACE ACV and the self-propelled LACV-30 was structured to meet specific operational objectives. As specified in the Test Plan (Reference 8), the ACV's were to be operationally tested to collect data which were necessary both to satisfy the objectives and to evaluate the craft's suitability for icebreaking operations on the Illinois and/or Mississippi Rivers.

The major objectives to be met during the testing of the ACV's were as follows:

- Demonstrate the use of ACV's to facilitate marine transportation on the Illinois and/or Mississippi River.
- Develop operational procedures for ACV's on Western Rivers.
- Evaluate the cost effectiveness of icebreaking ACV's for facilitation of river commerce.
- Determine personnel training and support needs of ACV icebreaking operations.
- Determine design criteria for future ACV icebreaking operations.
- Demonstrate the potential of self-propelled ACV in ice jam control and flood control.

GENERAL CHARACTERISTICS

• OVERALL LENGTH	114'-6"
• LENGTH BETWEEN PERPENDICULARS	108'-6"
• BEAM (EXTREME)	30'-3"
• DEPTH (MOLDED TO MAIN DECK)	10'-0"
• DRAFT MEAN (FULL LOAD)	7'-0"
• DISPLACEMENT (FULL LOAD)	390 S. TONS
• THREE DIESEL ENGINES	800 SHP MAX./UNIT

IDENTIFICATION TABLE

1 RADAR ANTENNA
2 SEARCH LIGHT
3 BRIDGE
4 "SPUD" ANCHORS
5 PUSHING KNEES
6 9" "V" SHAPED ICE DEFLECTORS BETWEEN KEEL COOLERS
7 8" ICE FENCE DEFLECTOR PLATES FOR SIDES OF KEEL COOLERS
8 9" "V" SHAPED ICE DEFLECTOR
9 14" ICE KNIFE (1 OF 6)
10 FLANKING RUDDER (1 OF 4)
11 PROPELLER
12 RUDDER (1 OF 3)
13 LIFE BOAT
14 LIFEBOAT CRANE

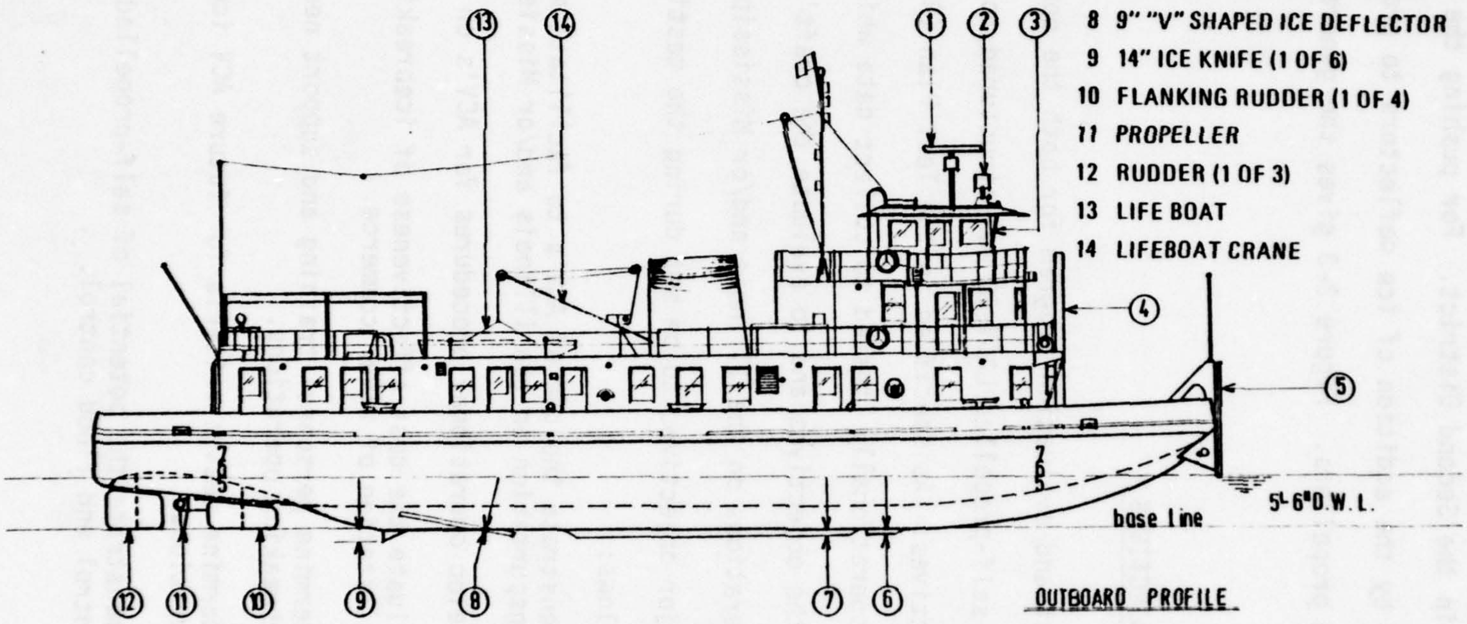


Figure 3-3: United States Coast Guard Cutter-Sumac

The test plan scenarios were constructed to collect operational and technical data which could be used to satisfy these objectives. However, it became apparent very early in the program that complete quantitative information could not be obtained for some of the objectives because of problems with equipment, weather, ice environment, barge traffic, scheduling and operational limitations. Accordingly, little information was actually acquired on the cost effectiveness objectives. Also, whereas training and support needs and design criteria were not addressed in depth, sufficient data were collected and subjective observations were made by experienced investigators to produce valid conclusions and recommendations.

A Steering Committee was formed which met periodically in Peoria to redirect the priorities of the individual tests within the overall objectives of the Test Plan.

5.0 OPERATIONAL SUMMARY

As part of the Test Plan, a set of 14 specific tests was identified. Initially, the individual test descriptions were developed for the MACKACE ACV and subsequently adapted to the LACV-30. In all, 57 different tests were conducted and documented for both craft. On the MACKACE alone, 35 individual tests were conducted with multiple runs for a total of 105 data items. Details of engineering data items recorded are contained in Volume 2 of this report.

A summation of activities of each craft is presented in Table 5-1.

SUMAC/MACKACE CRAFT			
	OPERATIONS (DAYS)	MAINTENANCE AND REPAIRS (DAYS)	OTHER (DAYS)
12-31 DEC	6	0	14
1-31 JAN	4	16	11
1-28 FEB	3	18	2
1- 8 MAR	3	1	4
TOTALS	21	35	31
LACV-30			
	OPERATIONS (DAYS)	MAINTENANCE AND REPAIRS (DAYS)	OTHER (DAYS)
15-31 JAN	1	14	2
1-28 FEB	14	7	7
1-18 MAR	12	6	0
TOTALS	27	27	9

TABLE 5-1. OPERATION TIME SUMMARY SUMAC-ACV AND LACV-30

The significant characteristics of the growth of river ice are related to the action of towboats in breaking the ice and churning the channel. Barge traffic in the channel is virtually an ice-making machine. As the ice is broken, a region of very heavy brash and slush ice is created in the channel by the towboats' propellers. Measurements revealed slush ice as much as 15 feet thick extending to the bottom of the channel. In addition, plates of ice 10 to 15 inches thick, which had broken away from the edge of the undisturbed ice field along the channel, would often become embedded in the slush. Some of this slush ice would then refreeze and form modules of ice five to eight feet across and three to six feet thick.

Figure 5-1 shows ice conditions on the Illinois River near Peoria, Illinois. Figures 5-2 shows an ice profile across the channel in Peoria Lake.

in Peoria Lake.

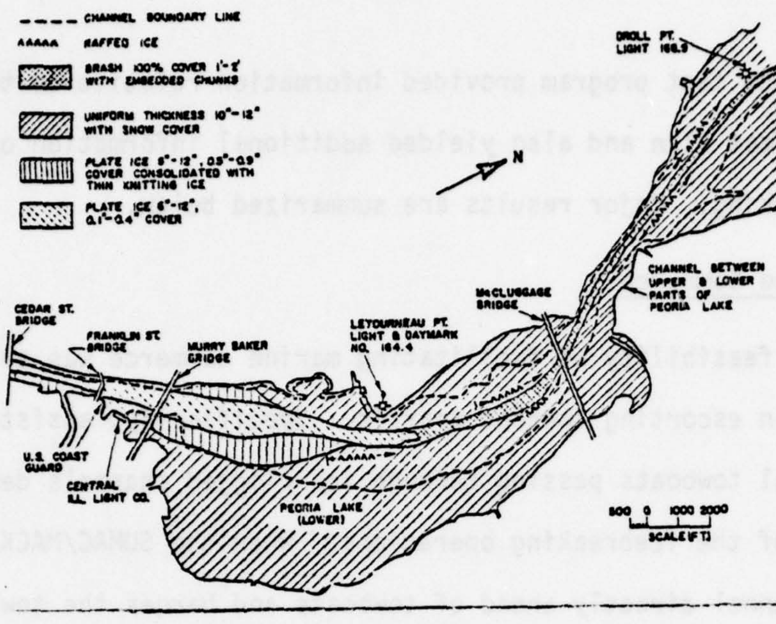


FIGURE 5-1: ICE CONDITIONS: ILLINOIS RIVER

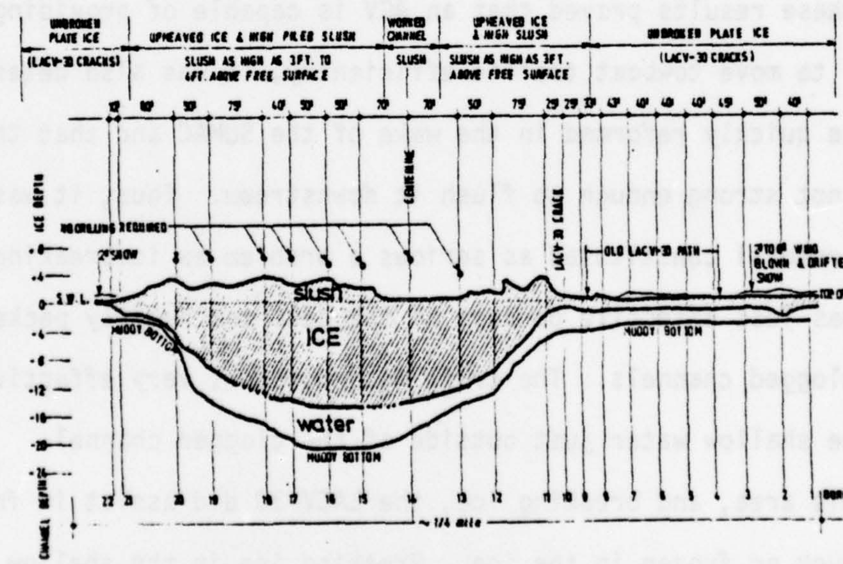


FIGURE 5-2: ICE PROFILE, PEORIA LAKE

(Note: Figure 5-2 Ice Profile taken 75 yards north of Sand Point Light, looking North upstream.)

6.0 TEST RESULTS

The results of the test program provided information relative to the requirements of the Test Plan and also yielded additional information on ACV technology in icebreaking. Major results are summarized below.

Facilitation of Marine Commerce

The operational feasibility of facilitating marine commerce was evaluated by conducting tests in escorting towboat traffic. Specifically, assistance provided to commercial towboats passing through ice-clogged channels demonstrated the utility of the icebreaking operations. When the SUMAC/MACKACE craft cleared the channel directly ahead of towboats and barges the towboat operators reported that less horsepower was required to operate their vessels at a given speed and that greater speed could be achieved at constant horsepower. Although these results proved that an ACV is capable of providing a broken ice channel to move towboat traffic efficiently, it was also determined that the broken ice quickly reformed in the wake of the SUMAC and that the river current was not strong enough to flush it downstream. Thus, it was apparent that ice removal constituted as serious a problem as icebreaking.

The LACV-30 was less effective because of the deep and heavily packed brash ice in the clogged channels. The craft was, however, very effective in operating in the shallow water just outside of the clogged channel. By operating in this area, and breaking ice, the LACV-30 did assist in freeing barges or boats stuck or frozen in the ice. Breaking ice in the shallow areas relieved the ice pressure on stranded vessels and allowed them to free themselves. This was demonstrated during several operational tests.

Operational Procedures

One of the objectives of the test and evaulation effort was to determine ACV icebreaking operational procedures for both barge-type and self-propelled ACV's. The operational procedures are based on observations and measurements taken during the test and evaulation effort and are to be used as a guide, not procedures to which either type of ACV must rigidly adhere.

- Nonself-propelled ACV Icebreaking -- The recommended operational procedure for a nonself-propelled ACV is broken down according to required maneuver vs. the ice environment (Table 6.1).
- Self-propelled ACV Icebreaking -- Only those operational procedures with a self-propelled ACV which are unique to a river ice environment are listed. Although some icebreaking results from cushion pressure, the most effective mechanism is by wave generation. In order to operate effectively, the ACV pilot must be aware of the status of the wave he is generating. This is presently obtained by a crew member who relays the information to the pilot in the cabin (Table 6.2).

Facilities/Personnel Requirements

The MACKACE ACV is a simple, conventionally designed barge, while the LACV-30 is more representative of aerospace design. However, neither is outside the technical capability of Coast Guard personnel because the sole unique features of either ACV is its specialized fabric skirt system. Some on-the-job training for both operators and maintenance personnel will be necessary, since the river ice environment is extremely harsh and constant vigilance is necessary to guard against serious malfunctions. It is clear that, since the LACV-30 is a much more sophisticated craft, personnel training and maintenance facilities requirements for this vessel would be

MANEUVER \ ICE ENVIRONMENT	THICK UNIFORM PLATE ICE	HEAVY BRASH ICE
Channel Clearance	Speed should be maintained (4 to 5 mph) to keep the momentum up and to sweep the channel as wide as possible. ACV should be bow up 1 to 1.5 degrees. Ballasted only as much to equal cushion pressure and ice thickness plus a pressure margin.	Speed should be maintained (3 to 4 mph) as long as cushion area does not become clogged. If clogged, push boat must back down to clear cushion. Bow up 1. to 1.5 degrees. Increase fan flow rate to reduce possibility of tuck-under of skirt.
Enlargement of Turns in Channel	Break out channel width on outside of turns in channel to allow the towboats to swing stern around to expedite turn.	By starting on the largest radius of the turn make an icebreaking run to widen the turn, each one closer in to the inside of the turn. This is to move the heavy brash away from the outside of the turn.
Towboat Assistance	Use channel clearance description. Stopping to allow towboat to catch up if channel closes up too quickly.	Speed of icebreaking should be geared to speed of the towboat which is being assisted. Because heavy brash closes in much more quickly than plate ice, the icebreaker must operate more closely to towboat.
Passing	When passing a towboat or barge speed should be kept up to maintain controllability.	To pass in a narrow channel one of the two passing vessels may have to stop to allow the other to move around and into the channel ahead or behind passed boat. There is a tendency in brash to be "sucked" into a boat or barge being passed if it is in the channel and the passing boat must go outside.
Beaching	Make a pass along beach to clear ice from beach area. Get a running start to push the ACV up on the beach as far as possible. Stand by to drop spud to reduce slide back.	Same as uniform plate ice.
Turn Around 180°	Wide radius turns should be made with caution because of potential hazard to rudders. Turn in narrow channel should be made by alternate ahead and back movements to move the ice away from the stern in order to make the turn.	A wide radius turn may be made if channel width is sufficient (300 ft.). Full rudder, inside engine full astern, outboard engine full ahead. If channel width will not permit a full turn, backing will be necessary. Care should be taken to protect turning rudder by keeping them aligned with boat. Flanking rudder may be used for turning.
Backing Down	Turning rudder must be straight with track. Use flanking rudder if a turn is desired.	Turning rudder must be straight with track. Use flanking rudder if a turn is desired.

Table 6-1: Summary of Nonself-Propelled ACV Icebreaking Operations Procedures

MANEUVER	USE/ICE CONDITION
High Speed Low Amplitude Wave	Good for relatively thin ice, 6 to 8 inch wave propagates out bank to bank.
High Speed, Quick Slow Down to Hump Speed	Used on heavy fast ice (>18") to maximize wave for short duration.
Hump Speed	Carries maximum wave. Good for normal icebreaking rate up to 20 mph where ice pressure may be relieved by open water. Also used to reduce size of ice plates once broken out of large ice field.
Hump Speed, Side Slip	Used to carry maximum wave into thick ice and amplify wave at edge of ice field for short distance--from open water.
Edge Work	Using hump speed technique work edges of river where surface runoff water has weakened ice provided water depth is adequate.
Figure "8" or Crescent Passes	Used on edge of ice from open water where maneuvering room is available.
Criss-Cross	Used for hole enlargement when starting from a solid cover ice field repeated criss-cross is necessary to break up ice chunks as small as possible to reduce wave damping.

Table 6-2: Summary of Self-Propelled ACV Icebreaking Operations Procedure

more stringent and extensive. In addition to personnel training, specific facilities and support equipment for ACV's must be provided to facilitate field repairs.

Design Criteria

Of the many design criteria developed through the test and evaluation program, one of the most important was the determination of the type of skirt fabric that can best withstand the impact of river ice. The 60 oz. per sq. yard single weave, nylon fabric bonded with natural rubber that was used on the MACKACE ACV was unable to survive the ice environment. The LACV-30 used a two-ply material of several different weights, including 60 oz. per sq. yd., which was considerably more durable than the single-weave fabric.

The MACKACE craft design incorporated an anti-spray skirt, which contributed significantly to minimizing the amount of spray generated by the cushion. A spray suppression system would be desirable on self-propelled ACV's.

Characterization of Ice Conditions

During the test and evaluation program, there was a need to compare results from the various locations and time frames of test runs. In addition, it was necessary to compare ice environments in order to assess the effectiveness of icebreaking under varying craft configurations. A methodology for characterizing ice conditions was developed with the purpose of standardizing river ice environments. It is apparent that further work must be undertaken in this area if a full understanding of an operational ice environment is to be attained.

ng Mechanisms

echnology of ACV icebreaking is relatively new, and some new ideas aking mechanisms are presented in Volume 2 of this report. Based ation, these ideas represent an initial attempt to explain the responses of the two ACV's and the ice during icebreaking. From tudy of the icebreaking phenomenon under more controlled conditions, be possible to acquire knowledge which would be fundamental in more effective icebreaking vehicles.

ng Effectiveness

asure icebreaking effectiveness, it is necessary to correlate the onment, the type of vehicle used and the effect the broken ice has or tows following behind. It would appear that the most straight- ay of defining icebreaking is to compare the area of ice broken per r the same conditions of ice thickness, strength, snow cover, etc. nce, the SUMAC/MACKACE craft broke ice on an average of 20 acres and the LACV-30 recorded 17 acres per hour. However, these s give no indication of the degree of resistance of the ice to the process nor do they relate to how well the ice was broken. What is that effective icebreaking requires breaking the ice and clearing possible channel. Using data from the Test and Evaluation Program, attempt has been made to develop a method for describing more icebreaking effectiveness. Further development of this methodology ed.

Icebreaking for Flood Control

The LACV-30 was deployed for a flood control operation on the Kankakee River (Illinois) for 18 days. The LACV-30 effort was highly successful and, according to the U.S. Army Corps of Engineers, Chicago District, it was responsible for averting possible serious flooding in the lower Kankakee River area.

7.0 CONCLUSIONS AND RECOMMENDATIONS

Based upon the analysis and results previously presented, and observations made during the operational tests, the following conclusions and recommendations are suggested.

Conclusions

- Air cushion vehicles did break ice in a river ice environment.
- The major problem on the Illinois River was ice clearance rather than icebreaking.
- There is a potential environmental problem associated with the high sound levels and wakes of gas turbine propelled ACV's.
- The Coast Guard can operate and maintain air cushion vehicles with selected additional training and additional support facilities.
- The design of the skirt material used on the barge-type ACV was inadequate for the river ice environment. Adequate materials are, however, available.
- The self-propelled ACV was effective in breaking ice to reduce potential river flooding.

Recommendations

- Perform a complete study of the Coast Guard icebreaking requirements in the Western Rivers.

- Consider evaluating self-propelled ACV's in a long-term multi-mission role.

- Investigate new techniques for better defining the river ice environment and develop better icebreaking effectiveness measures.

- Consider the development and operation of barge-type ACV's which are compatible with Coast Guard WYTL or WYTM icebreakers.

- Keep the towing industry informed, through a formal Technology Transfer Communication System, of the capabilities of nonself-propelled ACV's.

- Continue evaluation of self-propelled ACV potential in ice jam and flood control.

REFERENCES

1. Commandant (G-CPA/84) Memo 7100/1 of 3 May 1977.

2. Commandant (G-OOO-2/74) Memo 3900-15 of 3 June 1977.

3. G-DOE-3 letter 3936 Ser 30175 of 14 June 1977.

4. Contract (DOT-CG-74401-A) of 31 August 1977 to Mackley Ace (USA), Inc., Suite 1205, 1101 17th Street, N.W., Washington, D.C.

5. Memorandum of Understanding, 29 December 1977, between the Commandant, Coast Guard (G-D) and the Army (MERADCOM 3).

6. Contract (DOT-CG-81-78-1856) Engineering and Support Services of 29 November 1977, to Chi Associates, Inc., Arlington, Virginia.

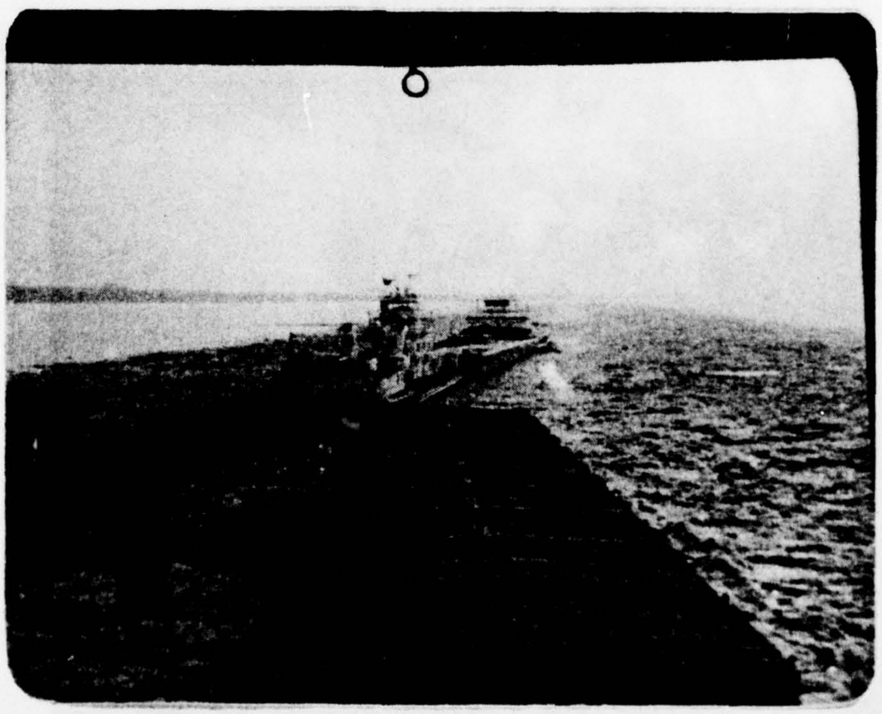
7. Air Cushion Vehicle Icebreaker Test and Evaluation Program, Volume 2: Operational and Engineering Analysis. Report, U.S. Coast Guard Research and Development Center, Avery Point, Connecticut, August 1978.

8. The Application of Air Cushion Technology to Ice-Breaking: Canadian Experience, Technical Report 1/77, Air Cushion Vehicle Division, Canadian Coast Guard, Transport Canada, January 1977.

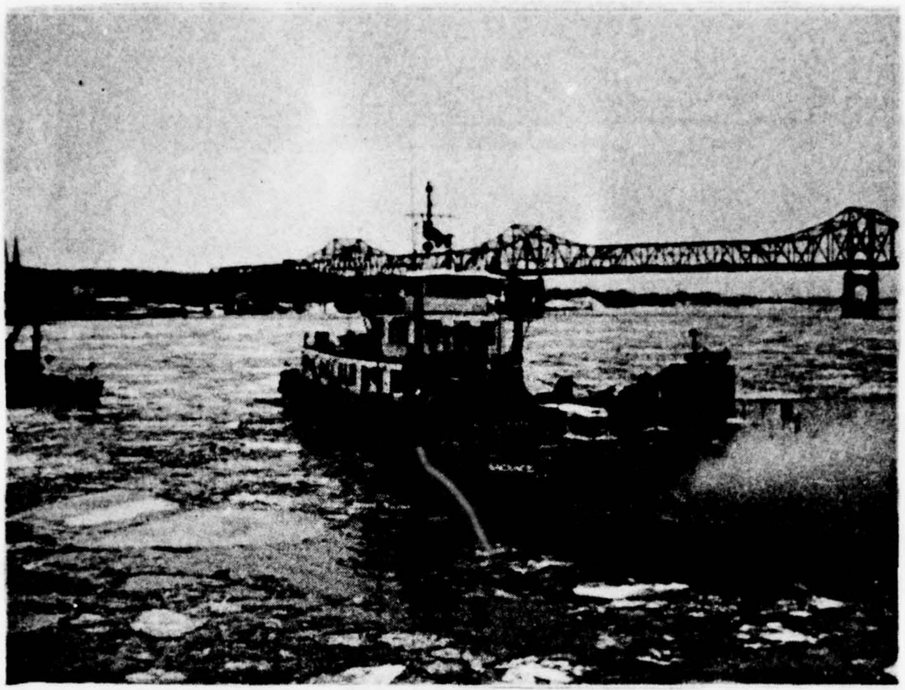
9. Test Plan for Air Cushion Vehicle Icebreaking, U.S. Coast Guard Research and Development Center, Avery Point, Connecticut, January 1978.

PHOTOGRAPHIC DOCUMENTATION

TYPICAL TOWBOAT TRAFFIC IN
OPEN WATER AND PLATE ICE



TOWS PASSING IN HEAVY BRASH
NOTE TWO BOATS PUSHING ONE BARGE

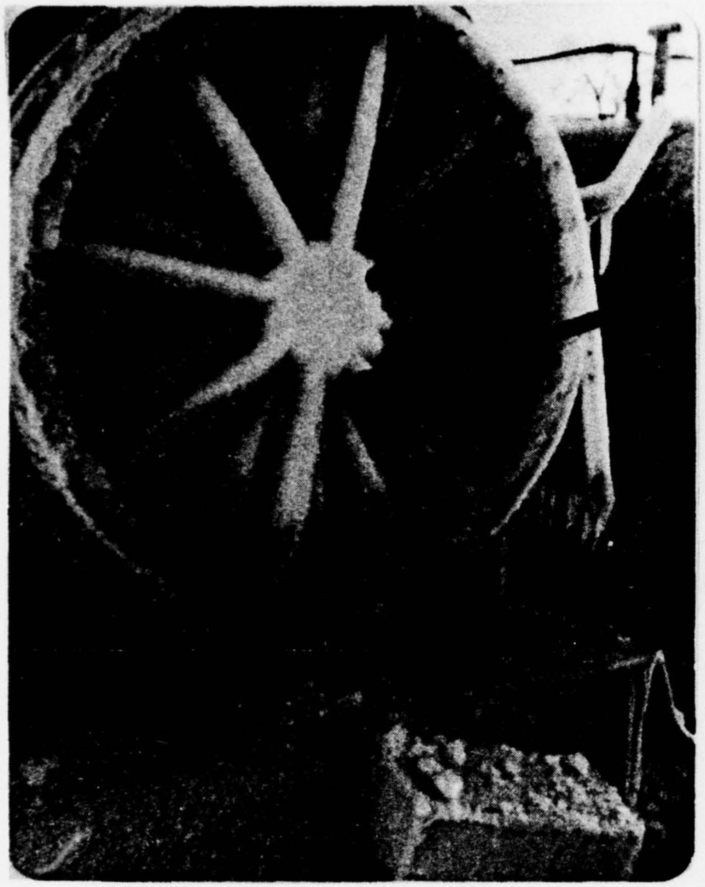


SUMAC & MACKACE ACV

MACKACE SEGMENT REPAIR

MACKACE ON HOVER SHOWING RIP IN SEGMENT

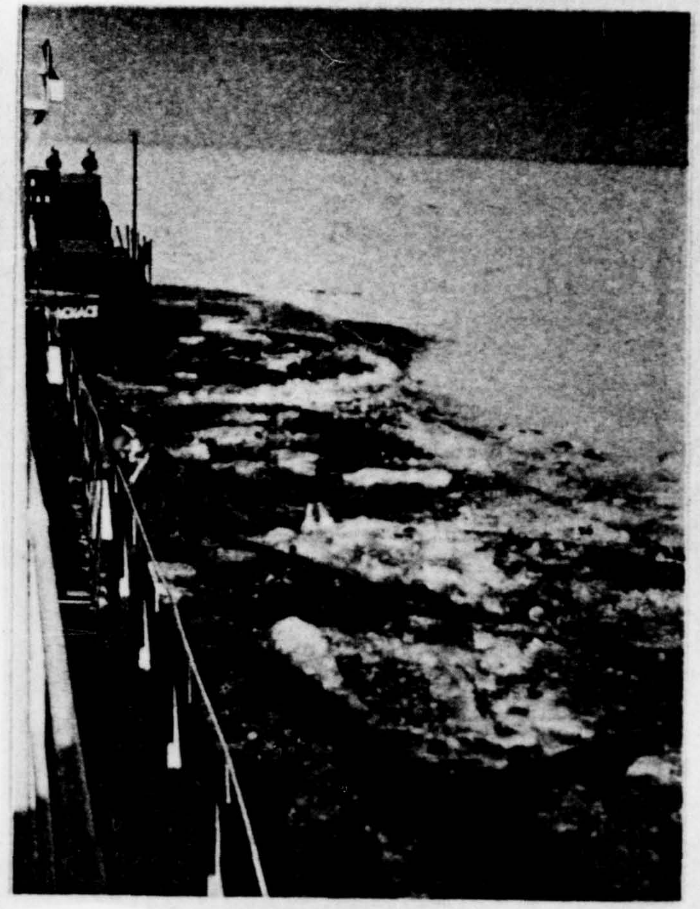
MACKACE REPAIR OF SEGMENT DAMAGE



MACKACE ICE ACCUMULATION
ON FAN INLET

LACV-30 ICE DAMAGE TO SKIRT

SUMAC/ACV - BRASH ICE CLOSING IN
AROUND HULL OF SUMAC



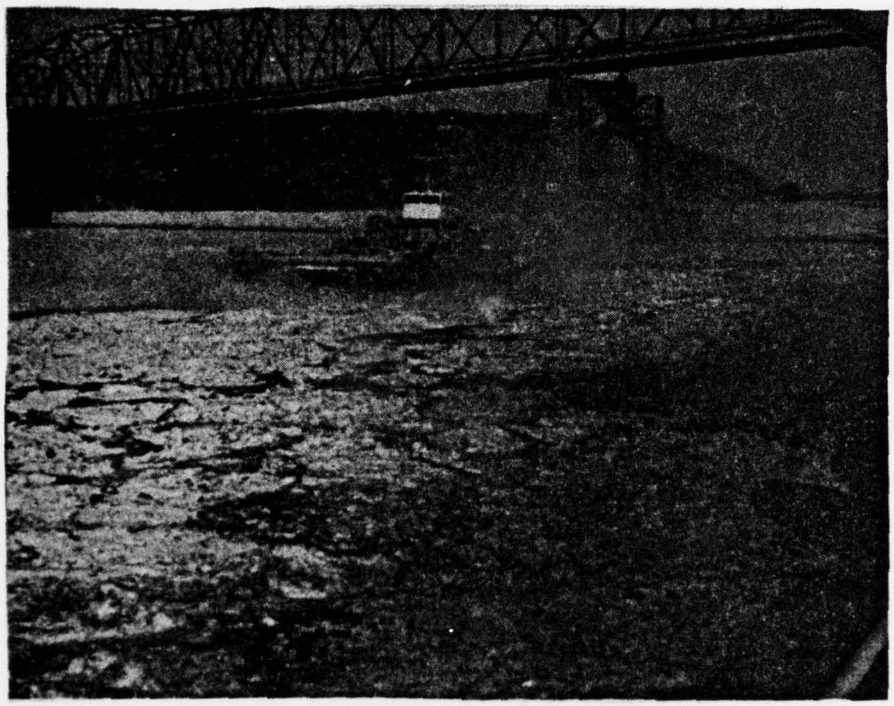
SUMAC/ACV - UNIFORM ICE BREAKING
2 TIMES WIDTH OF ACV

POLING ICE TO DETERMINE THICKNESS

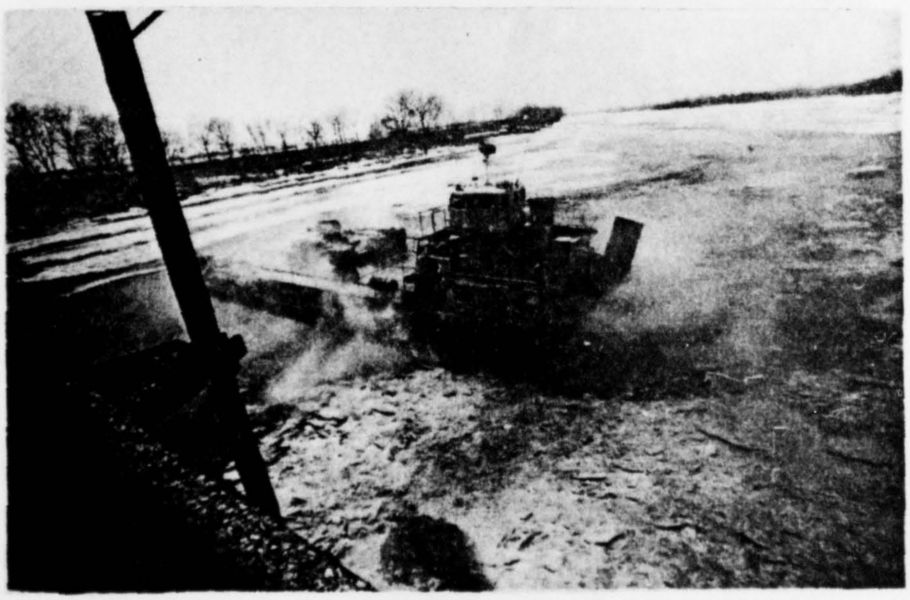
SAMPLING OF ICE FOR PROFILES

LACV-30 ICEBREAKING OPERATIONS

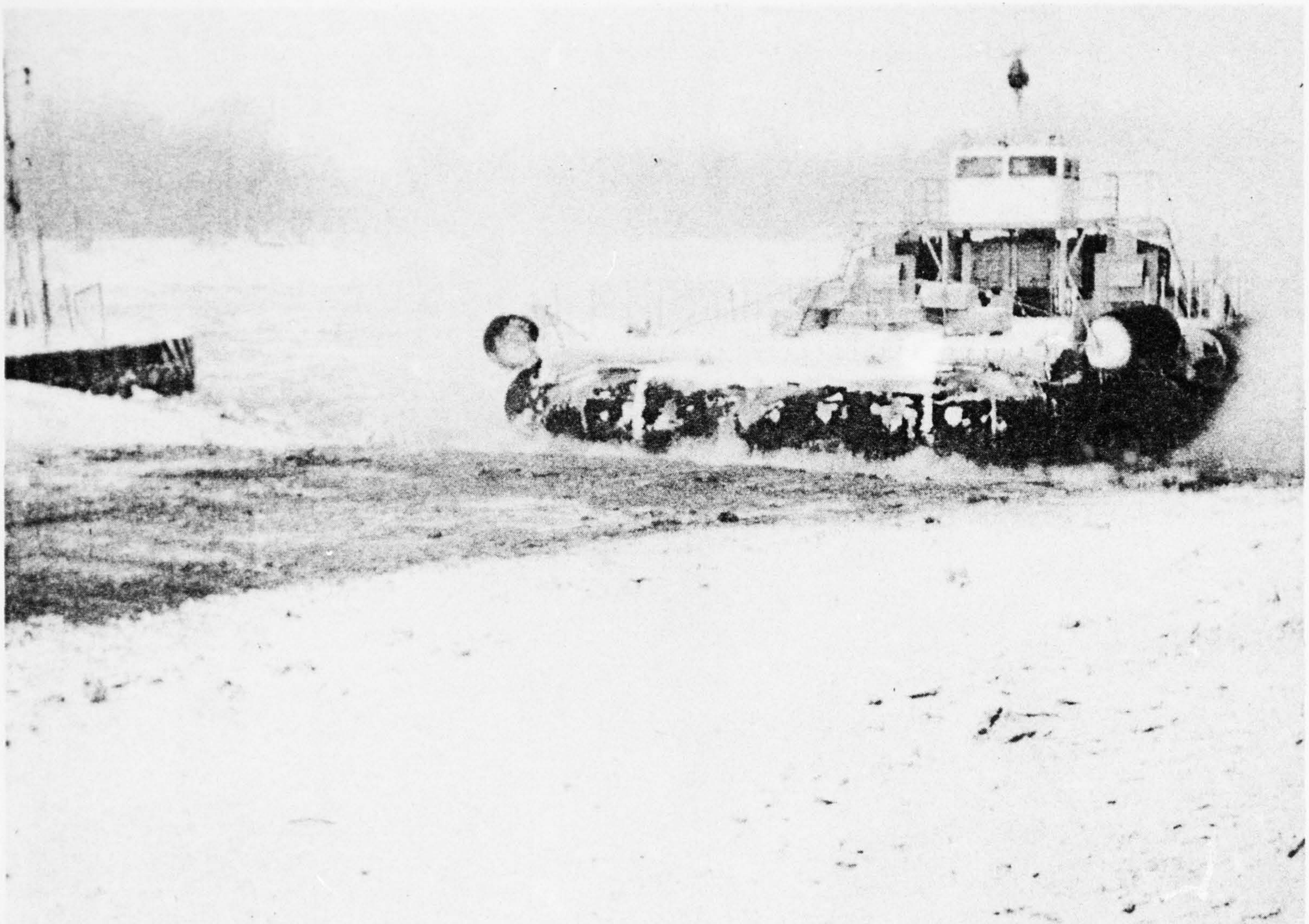
ILLINOIS RIVER



LACV-30 OPERATING IN TOWBOAT CHANNEL



LACV-30 BREAKING ICE FOR FLOOD
CONTROL KANKAKEE RIVER



LACV-30 COMING UP RAMP DURING

ICEBREAKING OPERATION

thickness, strength, snow cover, etc.

broke ice on an average of 20 acres
cres per hour. However, these
egree of resistance of the ice to the
how well the ice was broken. What is
quires breaking the ice and clearing
ta from the Test and Evaluation Program,
velop a method for describing more
Further development of this methodology

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